Chronometry of Extrasolar Planetary Systems

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Future space observatories capable of directly detecting Earth-sized planets around other stars are planned. These telescopes, operating either at optical or mid-infrared wavelengths, are designed to obtain photometric and spectral information on any detected planets. Dwarf stars within 50 pc of the Sun, the most likely targets of these missions, have ages ranging from ∼20 Myr to ∼10 Gyr. Three of the four terrestrial planets in our solar system have undergone significant evolution over the 4.6 billion year history of the Solar System, and their appearance would have been very different at different epochs. The Earth's early atmosphere may have contained higher concentrations of carbon dioxide and methane, and oxygen would have been absent. Water-carved features in ancient terrains on Mars have led to the hypothesis that a 5-bar carbon dioxide atmosphere enveloped that planet. The atmosphere and surface of Venus would have been substantially different if the planet was initially wet as has been proposed. Accurate planetary chronometry is necessary to interpret differences between planets to determine whether we are viewing planets of the same age on different evolutionary tracks (due to initial conditions or their distance from the parent star) or are viewing planets on the same evolutionary path but with different ages. Solar-mass stars arrive on the main sequence in about ∼20 Myr and thus most of the stars with detected planetary systems will be main sequence objects. Main sequence stellar temperature and luminosity is sensitive to both mass and age and this degeneracy makes their age (and that of any planet) difficult to determine precisely. I review the accuracy of different chronometry systems, including activity and rotation, Th and U radioisotope abundances, and astroseismology. I consider chronometry of planetary systems by the thermal evolution of constituent giant planets or brown dwarfs. Finally, I present calculations on the accuracy of stellar ages when the effective photosphere temperature is measured and stellar mass is constrained by direct measurements of a planet's orbital semi-major axis and period.